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Electric Blackout Prevention: Toward a Computer-Mediated Weather Alert Broadcasting Solution

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ABSTRACT

Electric power consumption is dependent on weather conditions. In most of the EU countries, power distribution is often subject to failure and it is frequent for the population to suffer power blackout. Within the solutions, deployed in order to avoid or face that problem, the public notification of blackout risks for a target region and the demand for reduced consumption are both interesting alternatives. This last solution is very basic but whatever meaningful. Consequently, automatic notification of cold weather and power distribution risks appears to provide many advantages especially when the alert is associated with the decision mechanism and supported by dynamic and virtual communication channels.

In this paper, we introduce a solution to broadcast weather alerts using MAS architecture associated with a Crisis Management enhanced XACML technology. This solution fosters the exploitation of a multi-layer approach required to be aligned with contextual constraints. In parallel, a decisional system allows managing the broadcasting of alert based on their utility for the population, as well as for the industry. The case study used to illustrate the feasibility of our approach exploiting weather and electric parameters and do not reflect the full constraints of any existing infrastructure in operation.

Keywords: Security; Incident reaction; Alert broadcasting; Multi-agents architecture; Decision mechanism; XACML.

1. INTRODUCTION

Many regions worldwide still keep nowadays suffering of electric power blackout [1] when weather temperature is significantly decreasing [2, 3]. As example, Brittany in France is one region that recently had to face such problems [4]. Brittany is a geographic and administrative region in the north-west of France (of about 13,136 square miles) that, for some years, suffers power distribution especially during very cold weather. For instance, the week between the 14th and the 18th of December 2009 was subject to important electric load foreseen. The expected load for Monday the 14th was about 85200 Mega Watts (MW) and during the evening (around 7PM), the load was expected to raise the historical level of 92400 MW. The influence of the weather conditions on the electric load is estimated at 2100MW by 1F°. This rate is important especially since we know that the temperature of the current winter is between 6 and 8F° higher than the average.

As electricity is a not storable good, its production has to fit precisely with its consumption. To maintain and guarantee that

balance, electric companies supervise the transport of the power and manage the electric network infrastructure. They keep watching in real time both production and consumption values to maintain the safety of the system. When these companies estimate that the situation is tense, they attend to face the problem with a set of solutions like i.e. the importation of power from the adjoining countries or by requesting the user to adapt the usage of electric machines like the washing machine or the dryer. Such requests are frequently made via TV and newspapers.

In this paper, we propose to enhance the system by defining a computer based Weather forecast Alert Broadcasting System (WABS). The system is elaborated based on a twofold architecture: the Multi-agent system (MAS) architecture [5, 6] that offers the advantage to be distributed and autonomous firstly. This MAS architecture is associated with the XACML [7] technology, which is adapted for the alert broadcasting on different communication channels [8]. Secondly, a decisional mechanism [9] permits to refine the broadcast of the alert based on contextual data [10] and on the weather forecasts by region. Decisions are made based on probabilistic and utility values. I.e. Informing a hospital of the risk of power cuts down has more utility than an office company. WABS main objective is to collect as much information as possible on the weather forecast in one hand, and the maximum of data regarding the consumption and the load of the network on the other hand. One main advantage of WABS is that it is structured according to the power network architecture and is able to integrate notions of geographic area, sub-area (region), and sub-sub-area (city) (see fig. 1).

The rest of the paper is structured as following: the next section introduces the MAS and depicts the broadcasting mechanism, section 3 introduces and analyses the decisional structure associated to the MAS, section 4 presents the related works and the last section concludes the paper.

2. MULTI-AGENTS ARCHITECTURE

Because of national politic constraints, the illustration of an architecture based on a real country was really not welcome. As a consequence for the usage of that paper, we have designed a fictive country named *Frost_Country*. This country is composed of four regions, namely *Bush*, *Desert*, *North* and *Waterfall*. Bullets on the map stand for cities. Electric power distribution in *Frost_Country* is enforced by high voltage electric lines that are: Double line for 240 MW, Dash line for 30 MW and Dote line for 5 MW. The MAS is composed of several components, named operators, which have different responsibilities.

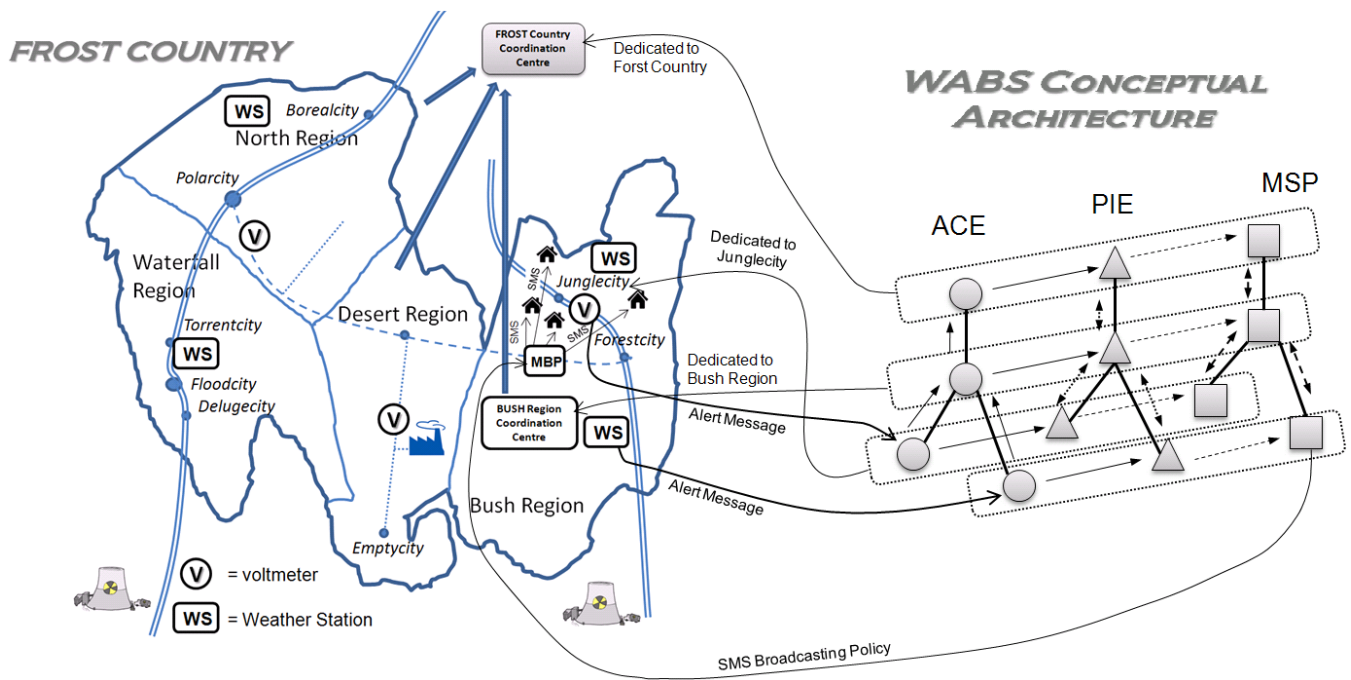


Figure 1. *Frost_Country* reaction architecture

Those operators are organized in two dimensions: the horizontal dimension structures the architecture in layers modeled based on the structure of the country. It allows adding abstraction in going upward: the lowest layer is closed to cities and towns and thus plays the role of interface between the targeted population and the management system. The higher layer corresponds to the country and is managed in the example by the *Frost_Country Coordination Centre*. It encompasses a global perception of the whole system and is able to take some decisions based on a more complete knowledge of the country's geography, administration and organizational constraints. Intermediate levels (1 to n-1) guarantee flexibility and scalability to the architecture in order to consider management constraints of the infrastructure. Those middleware levels are the regions. They collect regional information in the *Regional Coordination Centre*.

The vertical dimension contains the alert tree, the reaction tree and the deployment tree that are placed side by side and that composed respectively with the following component: (1) The Alert Correlation Engine (ACE) collects, normalizes, correlates, analyzes the alerts coming from the networks of probes. The confirmed alert is forwarded to the reaction decision component (2). The Police Instantiation Engine (PIE) receives the confirmed alert for which a broadcast is expected. The policy encompasses the broadcasting rules to be applied considering weather information. In view of the knowledge of the policy and of the geographical constraints and specificities, these components decide if a broadcast is needed and define if the message is to be sent. The messages varied from a single notification for information to a serious warning asking the population to react as a result (3).

The Message Broadcasting Point (MBP) instantiates and deploys the new message on the targeted networks. The deployment is made by the Message Supervising Point (MSP) that send the new message to the selected communication channels (Twitter, Facebook, SMS, ...[8]). The terminology

used is extracted from [7] regarding the ACE and the PIE. In parallel, some components of XACML have been adapted for the crisis reaction mechanism: PDP (Policy Deployment Point) has been specialized in a MBP. Both components' functions are the instantiation of a reaction or of a message in a crisis context. Additionally, the PEP (Policy Enforcement Point) has been specialized in a MSP. Both target the execution of the decision: enforcement of the IT policy for the PEP or broadcasting of the message for the MSP. Fig 1. explains how the three layers are mapped to *Frost_Country*. It is from top to bottom: The *Frost_Country*, its regions (*North Region*, *Waterfall Region*, *Desert Region* and *Bush Region*) and the city areas (i.e. for the *BushRegion*: *Junglecitcity* and *Forestcity*).

The MAS architecture is associated with a communication engine. That engine is based on a message format and on a message exchange protocol issued from [11]. The message format is defined in XML and is structured around a number of attributes that specify the message source, the message destination and the message type (alert, notification, warning, request to the population, request to the industry, level of the request, etc.). The protocol defines the exchange format and the workflow of messages between the architecture components. It encompasses a set of rules that governs the syntax, the semantics, and the synchronization communication.

The electronic institution based on agents provides the requisite characteristics to support the function of the operators. Hence, agents are assigned roles in order to specify their function in the architecture and the communication protocol is accordingly defined between them. Fig. 2 introduces the developed architecture illustrated by the weather forecast alert broadcasting.

The flow is supposed to begin with an alert detected by a probe positioned in a weather station based i.e. in the *Junglecitcity* or somewhere else. Have a look at the weather station of *Junglecitcity*. This alert is sent to the *Junglecitcity_ACE* agent (local layer). This agent has two choices: (1) Confirm the alert to the corresponding PIE (at the same level), or (2) Decide to forward the alert to an upper ACE (here *BushRegion_ACE*). This

decision to confirm the alert is explained in section 3. In this example, *Junglecty*_ACE agent decides to forward the alert to the upper level. Afterwards, like the ACE, the PIE agent has the possibility to confirm the alert to its corresponding MSP or to forward the alert to a higher layer (here *Frost_Country*_PIE). For this case the regional layer is sufficient, so the PIE sends the new policy to *BushRegion*_MSP. Once the MSP (at the appropriate layer) receives the policy instanced by the PIE, the policy is analyzed (this will be explained more in detail in the next paragraph) and sent to the appropriate MBP agent that knows how to transform the message in an understandable information for the target and according to the most suitable communication channel (SMS, social network, etc.).

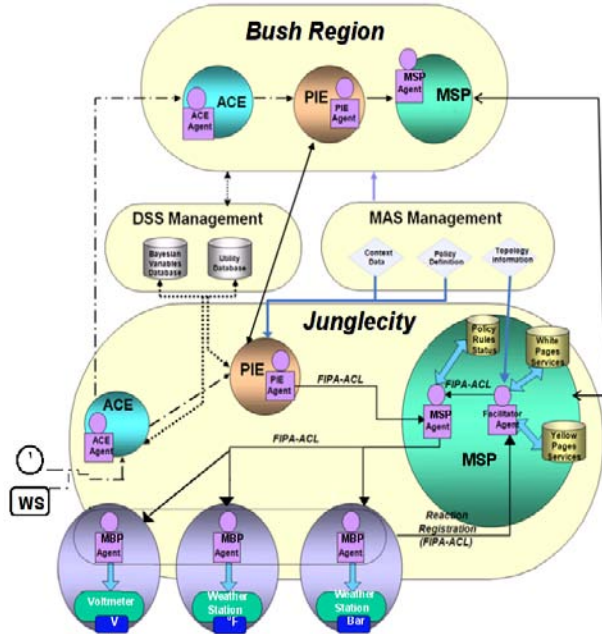


Figure 1. MAS reaction architecture

Message Supervising Point

A focused analysis of the MSP points out that it is composed of two modules (Figure 3). The Policy Analysis (PA) module performs a set of validation checks. It verifies the syntax of the *communication policy* specification provided by the PIE, and afterward verifies that newly received policies are consistent with the previously sent messages (recorded in the policy status database). A set of *communication policy* is consistent if no contradictory messages are found. If conflicts between messages are detected, the *communication policy* is sent back to the PIE.

The PA communicates with the policy rules status database that stores all *communication policies* and their current status (in progress, not applicable, by-passed, enforced, removed...). In addition, the module is able to detect rules that cannot be enforced due to a lack of MBP. As a consequence an MSP needs to be aware of the different managed MBP. Therefore the MSP agent is helped by a Facilitator agent. This agent manages the network topology by retrieving MBP agents according to their localization (cities, regions or countries), their target (hospital, citizen, industry, transport, airport, etc) and according to actions that it performs (send SMS, use social networks like facebook, etc.) For this, the Facilitator uses white pages and yellow pages services.

The Component Configuration Mapper (CCM) applies in detail the actions to be taken by the appropriate applications (SMS, social networks or press). This module receives high level policies and generates generic format policies for each type of MBP. To achieve that, it asks the Facilitator to determine which MBP are involved by the *communication policies* by mapping a set of possible actions to the effective communication channels. If some rules are not applicable, the component CCM notifies the PA which updates the policy rules status. Problematic rules will be passed by, and their status in the “policy status” database will change from *in progress* to *by-passed*. Finally, the *communication policies* are sent to the concerned MBP.

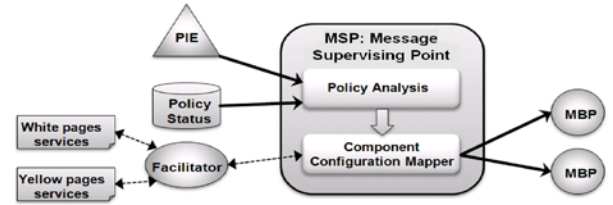


Figure 2. MSP architecture

The JADE [12] platform provides an implemented facilitator and searching services. Besides, the use of a MAS framework provides flexibility, openness and heterogeneity. Actually, when we decide to add a new MSP, we just have to provide its MSP Agent with the ability to concretely apply the policies that will register itself through the Facilitator, which will update the databases.

Message Broadcasting Point

The MBP agent (Fig.4) manages the communication channel associated to the WABS. Agents are specialized according to the kind of channel or the kind of message the channel has to deliver. I.e. SMS information messages are structured differently from a Facebook based alert information.

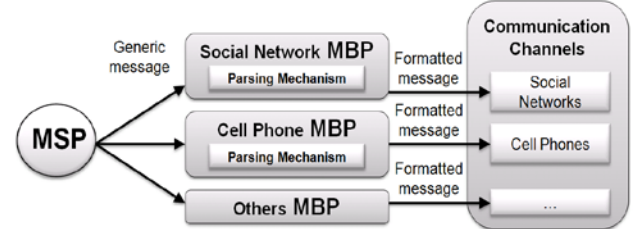


Figure 4: MBP architecture

To deal with that specificity, the MBP knows how to parse the communication represented in an abstract format (XACML [7] in our case) toward an interpretable and formatted message for a specific channel.

3. DECISION SUPPORT SYSTEM

The system provides mechanisms to make decisions in a range of situations like: conflicts between several communication channels or the necessity (or not) of communication escalation to the upper layer. One challenge of the DSS is the management of uncertainty. Uncertainty is defined as situation caused by a lack of knowledge about the environment when agents need to decide the truth of statement. Decision is a process [13] and consequently, it may be represented using its input and its output. For the weather alert communication, inputs of the alert

sending decision mechanism are for instance: the temperature, the pressure or the voltage of the alerts, the contribution of the system to weather crisis management (if any), or the criticality of that crisis. Outputs of the process are for instance: the escalation of the alert to upper ACE or its confirmation to the PIE.

As explained in [9], the decision-making mechanism is composed of four pillars: Ontology, BN, ID and Virtual Knowledge Community (VKC). In that paper, the VKC is not addressed because the use of the 3 first pillars is sufficient to understand the decision mechanism. The approach preferred to design the decision mechanism is studied from the research performed by Yang's thesis and is adapted for the weather alert reaction through a MAS architecture. This paper completes the Yang's research since our DSS is illustrated by a real architecture for weather crisis management.

Ontology

Ontology is the most import pillar in that it supports the BN and ID pillars. For the weather alert system, ontology is defined using the Web Ontology Language (OWL). Resource Development Frameworks (RDF) syntax is the most commonly used method to model information in OWL. It may be implemented in web resources and is structured based on the set [object, subject, predicate]. Both, object and subject are resources and predicate is an attribute or a relation used to describe a resource. In our *Frost_Country* case study, the DSS decides the transfer of an alert from the probe to the *Junglecity_ACE*, the forward of that alert to the *BushRegion_ACE*, and the confirmation of the alert to the PIE. On Fig 5., ovals stand for OWL class, solid arrow lines stand for RDF predicate, dash arrows for influence relations and rounded rectangles for set of domain value.

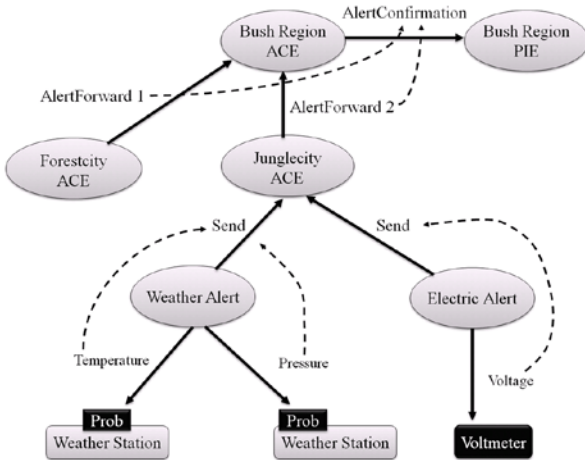


Figure 5. Decision system for weather alert transfer

The ontology permits to formalize the concept encompassed in the MAS architecture as well as their relations. However, at the ontological level of formalization, the uncertainty challenge remains unaddressed and the decision mechanism remained needed for the agents to take the decision. OntoBayes is an extension of OWL with two features: BN that address the uncertainty and ID that support the decision mechanism process.

Bayesian network extension

Bayes theorem is used to calculate conditional probabilities [14]. The calculation depends on prior knowledge that could be considered as uncertain. I.e.: the probability of high impact on the population of *Junglecity* if we have before a medium temperature alert.

	HasPPParameters	HasPValue
Cell_1	temperature.alert=low/ JunglecityPopulation.impact=low	0.75
Cell_2	temperature.alert=medium/ JunglecityPopulation.impact=low	0.35
Cell_3	temperature.alert=high/ JunglecityPopulation.impact=low	0.17
Cell_4	temperature.alert=low/ JunglecityPopulation.impact=medium	0.32
Cell_5	temperature.alert=medium/ JunglecityPopulation.impact=medium	0.91
Cell_6	temperature.alert=high/ JunglecityPopulation.impact=medium	0.48
Cell_7	temperature.alert=low/ JunglecityPopulation.impact=high	0.07
Cell_8	temperature.alert=medium/ JunglecityPopulation.impact=high	0.40
Cell_9	temperature.alert=high/ JunglecityPopulation.impact=high	0.69

TABLE I. BAYESIAN PROBABILITY

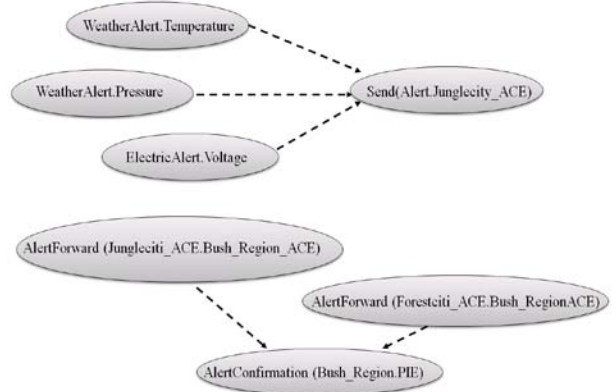


Figure 6. Bayesian graph models

The BNs extension introduces the parameters of that probability by specifying the following two perspectives: the qualitative and the quantitative. The qualitative perspective specifies the random variables explicitly as well as their dependencies and the later links quantitative information to those variables using OWL.

The specification of random variable and their dependency is performed by introducing the new OWL property element `<owl:ObjectProperty rdf:ID="dependsOn"/>` [9]. Accordingly, the qualitative extension may be represented by 2 Bayesian graph models (Fig 6, extracted from the Fig 4). The ovals represent Bayesian variables and the arrows specify their relations. The graph is to be read: i.e.1.: The alert forwarded from the *Junglecity_ACE* to the upper layer ACE has influence on the confirmation of the alert that is sent from the *BushRegion_ACE* to the *BushRegion_PIE*. I.e.2.: A voltage electric alert has influence on the action to send an alert to the *Junglecity_ACE*. The quantitative extension is performed with the association of a probability table to the Bayesian variables. In the case of the *Frost_Country*, quantitative probability P is provided by Table 1.

Influence diagrams extension

IDs extension aims at representing and analyzing a decisional model to support the decision-making process. The review of the literature that treats ID [15, 16] highlights that decision mechanisms are composed by three types of nodes: 1) Chance nodes that represent variables that are not controlled by the decision maker, 2) Decision nodes that represent choices available for the decision maker, and 3) Utility nodes that represent agent utility functions. Additionally, [17] explains that three types of arcs express the relationship between nodes: I) Information arcs (*isKnownBy*) that point out the information that is necessary for the decision maker, II) Conditional arcs (*influenceOn*) that point out the probabilistic dependency on the associated variable, and III) Functional arcs (*attributeOf*) that point out variables used by utility nodes as decision criteria.

Based on that structure of a decisional model, the alert transfer may be represented in Fig. 7. Ovals stand for Chance nodes, rectangles stand for Decision nodes, and diamonds stand for Utility nodes. The information arc relates to all information observed to make a decision and the conditional arc relates to data issued from Chance node and considered as evidence for the Decision nodes.

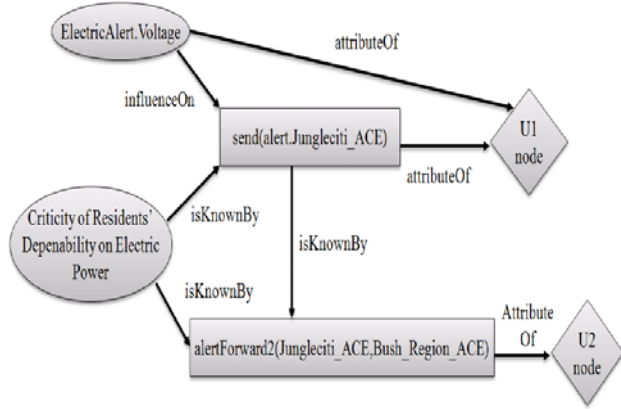


Figure 7. ID's graph model of alert transfer

Additionally, to make a decision, the agent that takes the decision needs to have its preferences quantified according to a set of attributes. The most important preference has a higher value whereas the worst has a lower one. To achieve this, the Utility node is associated with an utility table that gathers the preferences for all decision choices.

UtilityCell.	HasUParameters	hasUValue
Cell_1	send(alert.Junglecity_ACE)=yes electricVoltage.alert=low	-78
Cell_2	send(alert.Junglecity_ACE)=yes electricVoltage.alert=medium	45
Cell_3	send(alert.Junglecity_ACE)=yes electricVoltage.alert=high	100
Cell_4	send(alert.Junglecity_ACE)=no electricVoltage.alert=low	79
Cell_5	send(alert.Junglecity_ACE)=no electricVoltage.alert=medium	30
Cell_6	send(alert.Junglecity_ACE)=no electricVoltage.alert=high	-99
...		
Cell_15	send(alert.Forestcity_ACE)=yes electricVoltage.alert=high	85
...		

TABLE II. UTILITY FOR IN-LAN ACE ALERT SENDING

Table II shows these preferences for the *Junglecity_ACE* alert sending decision and is recorded in the utility database represented in Fig. 2. I.e. Cell_3 of Table II shows that the utility to send the alert to the *Junglecity_ACE* if the electric voltage alert is high (utility value of 100) and consequently that it is useful. In Cell_15, the table provides a utility value of 85 for the same alert but for the *Forestcity*.

As seen in Fig. 7, a sequential path between all decisions exists. Indeed, some decision depends on previous decisions and as a consequence, previous decisions (decision nodes) become chance nodes for next chance node. This figure illustrates that *send(alert.Junglecity_ACE)* is at the same time a decision node and a chance node that is known by the decision node *alertForward2(Junglecity_ACE, BushRegion_ACE)*.

4. RELATED WORKS

A scrutiny of the literature reveals that the problem of crisis management and alert system to handle exceptional situations based on MAS has been studied in recent years using different approaches. The work accomplished so far shows that MAS are suitable solutions for crisis situations, especially for Crisis Response Management (CRM) systems. MAS have been used to tackle disaster situation management tasks.

[18] investigates the requirement on the support of crisis response organizations by means of MAS. The research is focused on the distribution of information and the support of communities in sense of persons, like group of firemen, medicals team civilians, etc). More precisely the community is defined as a *group of people bound together by certain mutual concerns, interests, activities and institutions*. In MAS, agents are at least partially autonomous and have a local view of the system/situation. Moreover, like people in critical situations, agents are used together to solve complex problems.

In [19] a MAS is used in order to simulate evacuations of persons. Traditional crowd simulators are based only the positions of people and structures. For example the leadership is not taken into account, social interactions in a more generally manner. Since MAS are systems composed of multiple interacting intelligent agents (in this case people), the use of this technology in this context is appropriate again. This research is quite interesting but differs to our work in the fact that for us, agents are only software and enable the transmission of alerts to the population and to companies. Our agents are not human and the goal is not about optimizing the management of a crisis situation (in this case evacuation).

A further approach [20] uses discrete-event simulation (DES) applied to an agent-based model. Here the environment is modeled as a DES while the crisis response agents are modeled thanks to a MAS (using the JADE [12] platform). The MAS is implemented separately from the environment. This work is quite original since it seems that no prior research has combined agent-based solution and DES.

Again, multi-agents technology is used in [21] for crisis management in the transport domain. This work depicts a parallel with the Vehicle Routing Problem (VRP) which is generalized to the Pickup and Delivery Problem with Time Windows (PDPTW). The goal is to minimize the distance of the travel. Therefore, three kinds of agents are used: Dispatcher Agent, Execution Unit Agent and Crisis Manager Agent. The two first kinds of agents are cooperating in order to solve the problem of the PDPTW, while the Crisis Manager Agent is

responsible for the detection of crisis situations (for example by providing information about the traffic jam).

A more practical approach is presented in [22] with a proof of concept implementation of an organizational-based model. This model is especially designed to support the dynamics of crisis management during crisis escalation. One of the advantages cited for this type of simulation is the low cost compared to real-life simulations. Moreover, real-life simulation involves the personnel. This simulation uses the Netherlands' case and is based only on the level of the severity of the disaster. The crisis response management can be taken at different level (local, regional, etc.) by appropriate authorities. The difference to our work is that their model is only driven by roles assigned to actors of the response (police: maintain order, fireman: save people). Our model uses a decision support system which takes decisions at different levels according to various alert parameters such as temperature or load of the electric network. Furthermore we are able to refine the scope of the response thanks to our model's different layers of MBP and MSP.

5. CONCLUSIONS AND FUTURE WORKS

In this paper, we have presented a solution to broadcast weather forecast alerts messages using a MAS based architecture associated with the XACML technology adapted for the alert broadcasting on different communication channels. The solution is composed firstly by a MAS that offers the advantage to react quickly and efficiently against an electric power or weather forecast alert while being adapted for heterogeneous and distributed communication channels. Secondly, a decision support system helps agents to make decisions based on utility preference values. This is achieved by taking uncertainty into account through Bayesian networks and influence diagram.

The architecture has been illustrated based on fictive country named *Frost_Country* that suffers blackout when the weather is extremely cold. Accordingly, our solution offers the possibility to introduce contextual information in the decision mechanism like i.e. the criticality of the electric power for the target users.

The decision support system has been explained for the transfer of an alert from the alert correlation engine to the policy instantiation engine. Other decisive points exist within the architecture. All of them could be solved using decision support system but they are not explained in the paper.

The future works based on our achievements will be the specification of a protocol, specification of the messages and thus the reaction methodology service oriented based. This protocol and methodology will be dedicated to the architecture presented in this paper and address the interoperability issues with regard of the policy representation and modeling.

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